ON THE STRUCTURE AND DYNAMICS OF SINGLE AND DOUBLE HELIX VORTEX BREAKDOWN

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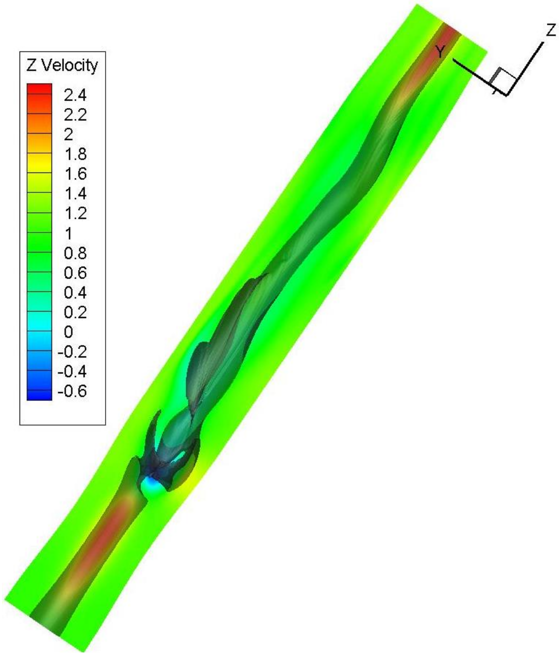
Vortex breakdown has intrigued the scientific community for exactly six decades now. It has firstly been discovered in 1957 by Peckham et al. as the bursting of a leading-edge vortex in the flow over a delta wing [1]. Since its initial discovery, it has been found in many more flow topologies, ranging from rotating pipe and jet flows to enclosed cylinder flows. Currently, no less than 7 different types have been identified, amongst which the most common ones observed are bubble and spiral breakdown [2]. Despite the extensive research, there is currently no general accepted theory which could explain all of the observed features of vortex breakdown. The reason is mainly because of the very complex nature of the phenomenon. For example, both spiral and bubble breakdown have been observed within the same experiment without changing the inflow conditions. Recent studies showed some more insight in the mechanism leading to breakdown. It was found that flows going from below to above the critical state become unstable [3,4]. Moreover, it has been shown by numerous authors that spiral breakdown occurs in the wake of an axisymmetric breakdown as a global instability mode of the flow [5,6]. Two modes of spiral breakdown have been observed: the single helix (|m|=1) and the double helix (|m|=2), where m is the azimuthal wave number.

In helping to understand the physical phenomena leading to breakdown, this paper focusses on the structure and dynamics of spiral breakdown. Both numerical simulations of an open pipe flow and experimental data of an annular show the capability of the theory of Benjamin [7] to predict the break-up of the vortex core into a spiral. This indicates that vortex breakdown is the transition from a super to a subcritical flow. Once the bubble has formed, its wake is unstable and a single or double helix emerges in the flow field.



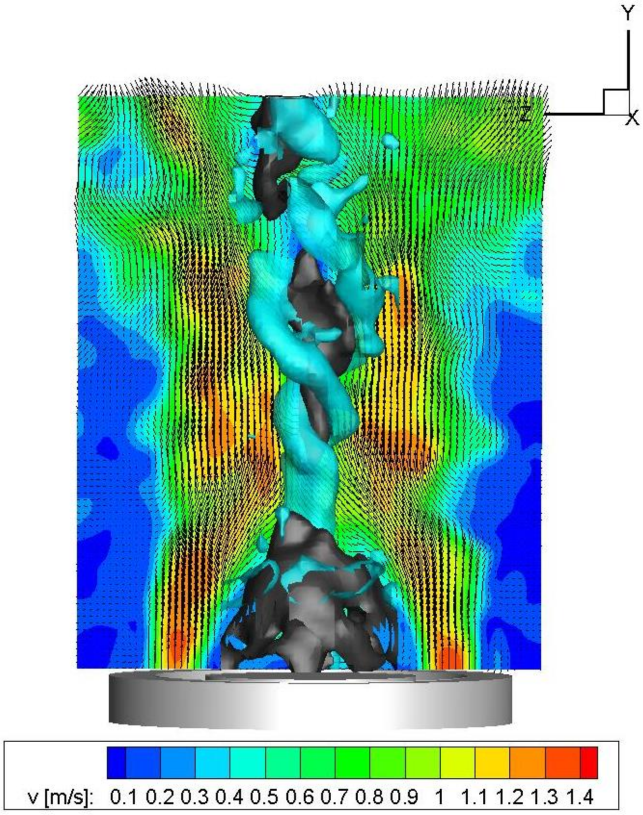


Fig. 1. Top: Vortical structures in an open pipe flow and axial velocity contours. Bottom: Vortical structures in an annular swirling jet. Both structures are visualized by the Q-criterion.

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